The California Nitrogen Assessment:

Summary of the Statewide N Mass Balance

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Why is N important to California?

Nitrogen is an essential nutrient for plant growth (often the most limiting nutrient)

Nitrogen fertilizers (both synthetic and organic) help to boost yield and sustain California agriculture.

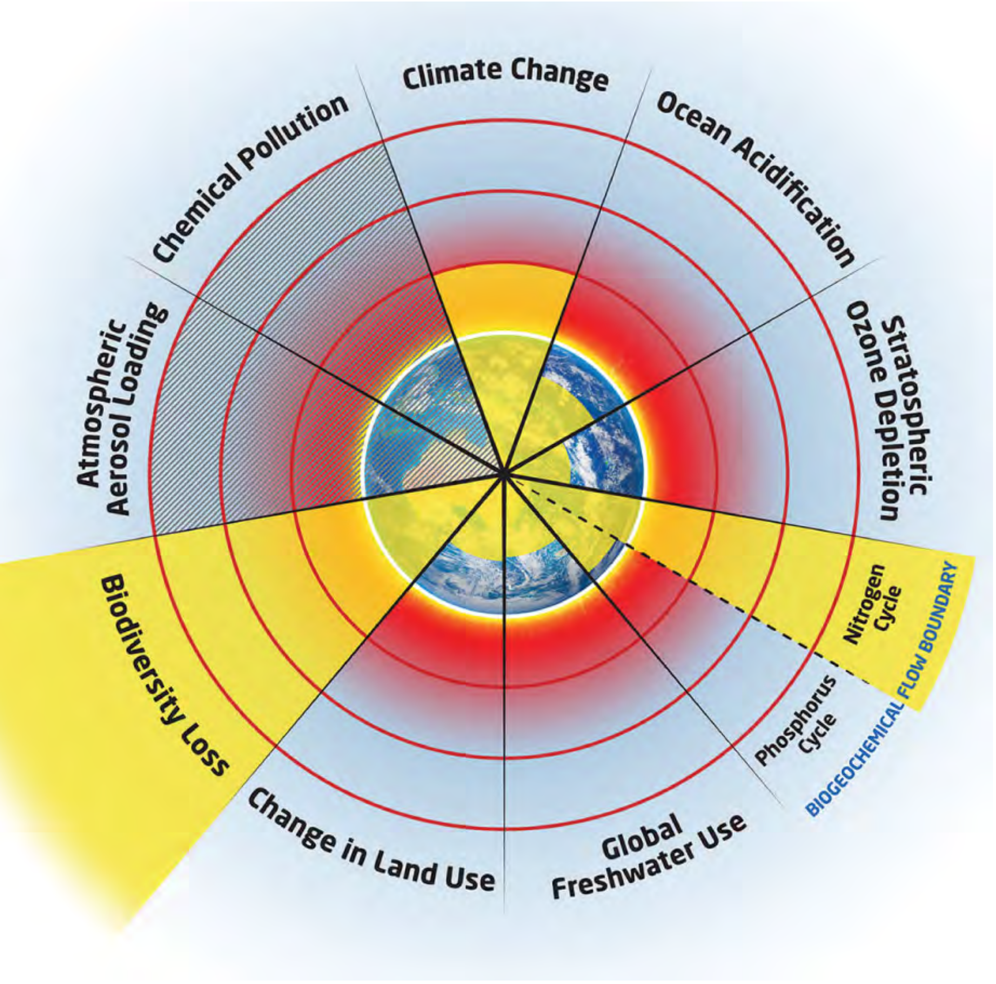
- **50% of US fruits, nuts, and vegetables**
- **21% of US dairy**

Despite improvements in N management and technology in recent years, there remain important tradeoffs and costs associated with N loss to the environment.

- **Water and Air Pollution**
- **Climate Change**
- **Human Health**
- **Biodiversity and habitat**

Too little N limits ecosystem processes… too much transforms ecosystems profoundly.

Millennium Ecosystem Assessment (2005)



On a global scale from 1960 - 2000

- Food production more than doubled.
- Food supply/capita increased (but not everywhere).
- Flows of biologically available N doubled in terrestrial ecosystems due to human activities.
- Flows of phosphorus tripled.
- Humans have changed ecosystems more rapidly and extensively than in any time in history.
- Increased reactive N plays a role in:
  - Air and water pollution
  - Eutrophication
  - Biodiversity losses
  - Climate Change
  - Ozone depletion

What the California N Assessment Covers

Underlying & Direct Drivers of N Cycle in California

- What factors and activities influence N cycling and flows into the state?

Statewide N Mass Balance for 2005

- How much N is coming into and out of the state?
- What are the main sources, flows and sinks?

Ecosystem Services: What are the positive and negative impacts of N on..

- Production of Food, Fiber & Fuel, Human Health
- Air Quality, Water Quality, Climate Change
- Cultural Values (e.g. recreation, landscape aesthetics, heritage, spiritual value…)

Future Scenarios Drawn from Stakeholder Engagement

- What are the potential economic and policy futures for N in California?

Technical Practices & Policy Responses to Manage N in California

- What can we do as a society to minimize the impacts and maximize the benefits?

The Assessment Process

An assessment is a critical evaluation of scientific information for the purposes of guiding decisions on a complex, public issue.

Stakeholders define the topics and set assessment questions.

The *process* is as important as the results and outputs produced; credible, useful, and legitimate.

Assessing what is <u>not known</u> and <u>uncertainty</u> in the data is as important as understanding what is known. (Gap Analysis)

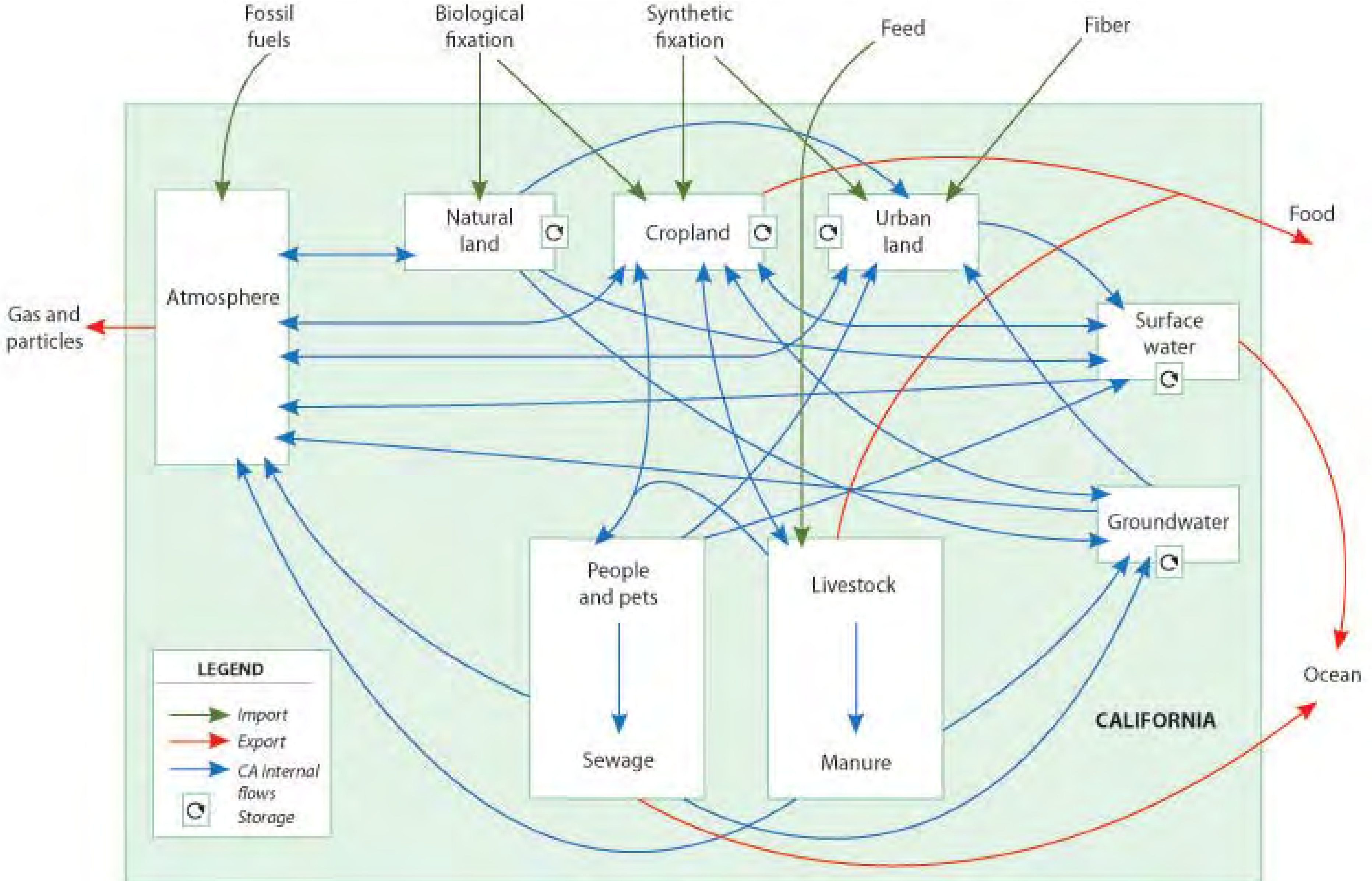
Peer reviewed (Researchers and Stakeholders).

Source: Millennium Ecosystem Assessment

A Mass Balance of California N, *circa* 2005

N Inputs = N Outputs + Δ N Storage

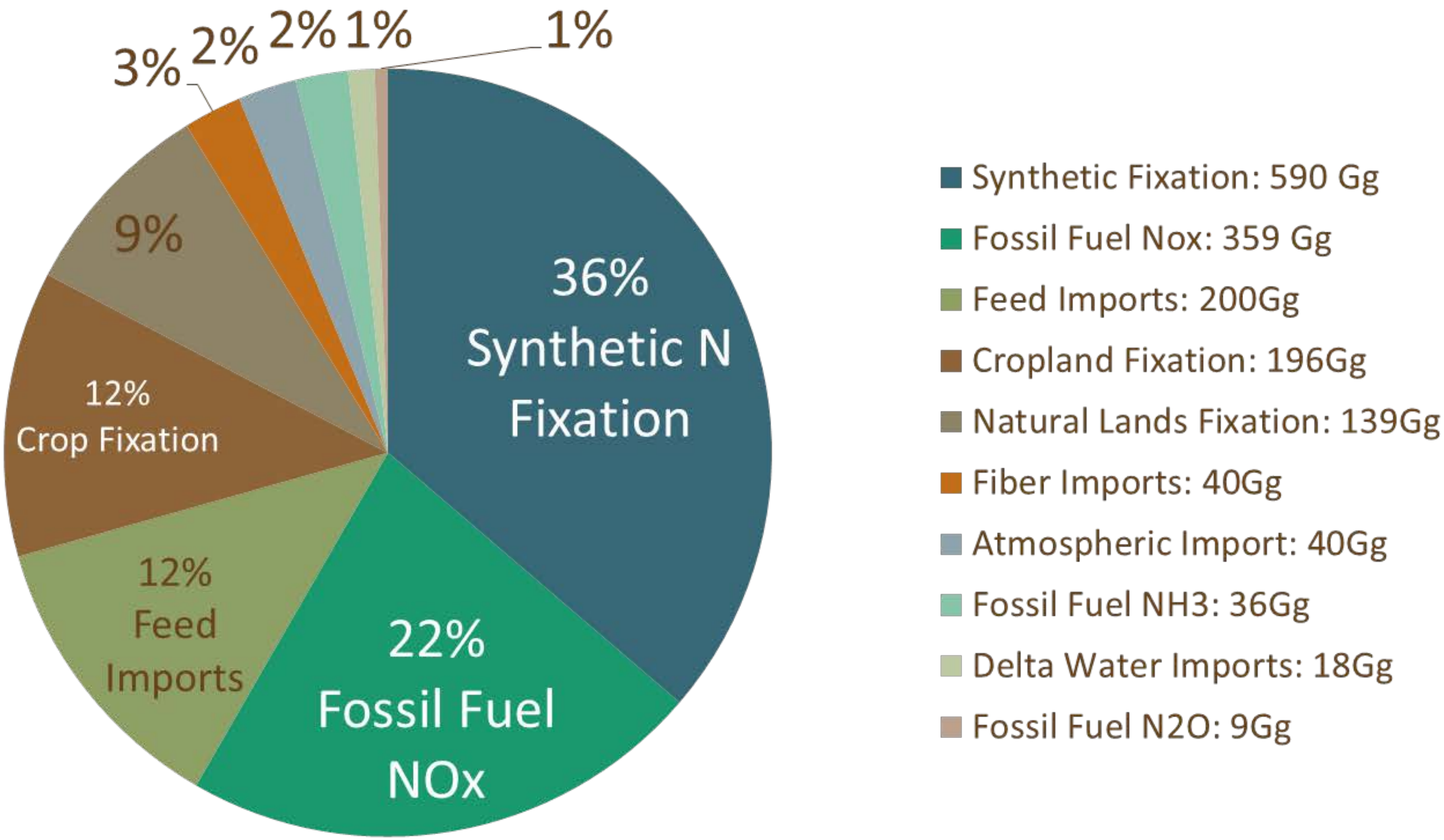
Flows of Nitrogen in California



Statewide N Inputs:

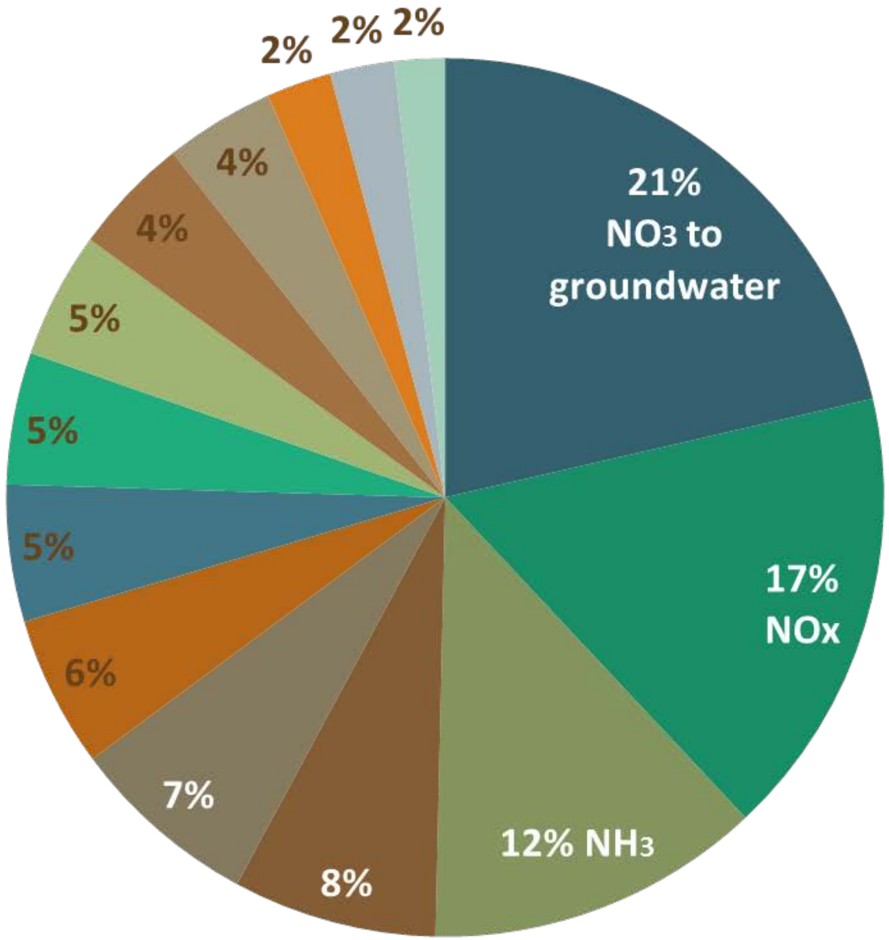
≈1.8 million tons N per year (1628 Gg N yr^{-1})

(1% of global human N inputs)



Statewide N Outputs and Storage Excluding Groundwater Denitrification

≈1.8 million tons (1628 Gg N yr^{-1})

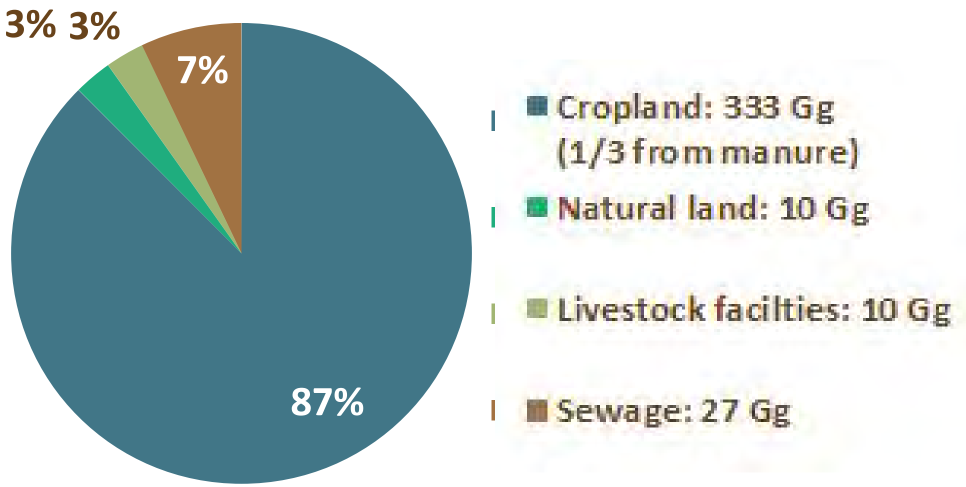


- NO3 to Groundwater: 348 Gg
- Nox: 270 Gg
- NH3: 201 Gg
- Other Urban Storage: 122 Gg
- N2: 113 Gg
- Natural Land: 91 Gg
- Sewage Discharge: 82 Gg
- Food: 79 Gg
- Urban Land: 76 Gg
- Landfills: 71 Gg
- Cropland: 66 Gg
- River Discharge: 39 Gg
- N2O: 38 Gg
- Reservoirs: 20 Gg

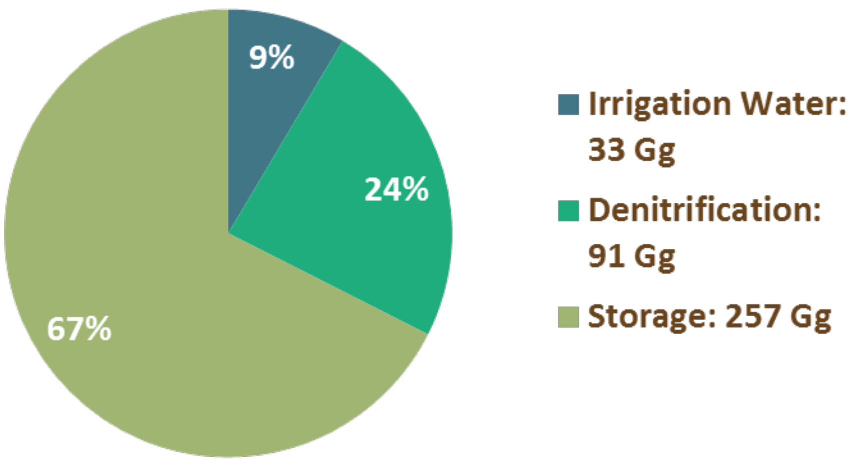
NO_3 Groundwater Mass Balance:

(Net nitrate groundwater storage = 16% of total statewide N)

NO3 flows to groundwater
381 Gg N (419 thousand tons)



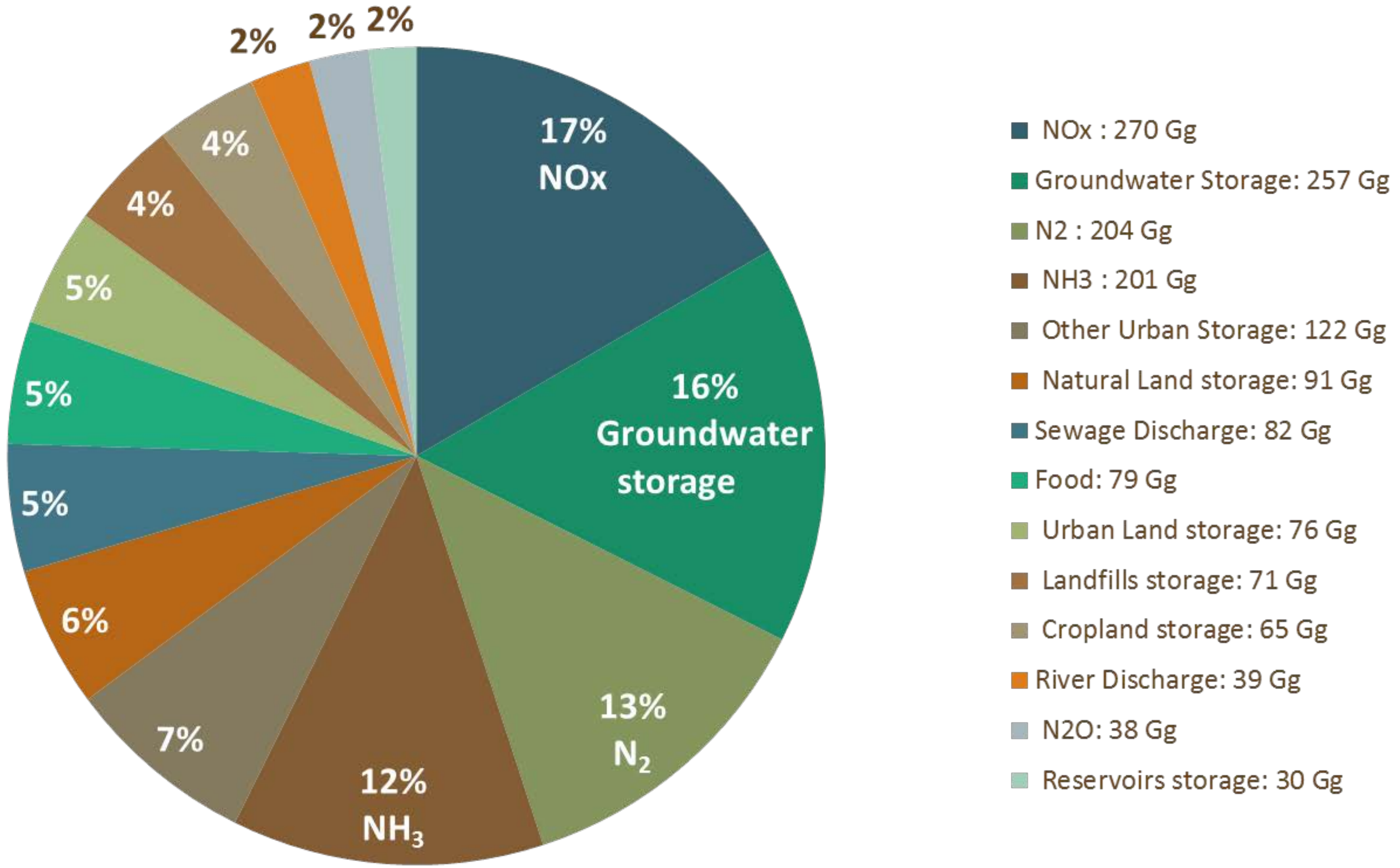
NO_3 outputs and net storage
381 Gg N (419 thousand tons)



Considerable uncertainty exists regarding the rate of groundwater denitrification in CA aquifers . $NO_3 \rightarrow N_2$ (some N_2O) Mediated by denitrifying bacteria (facultative anerobes) – requires labile organic C as an energy source (or S , Fe).

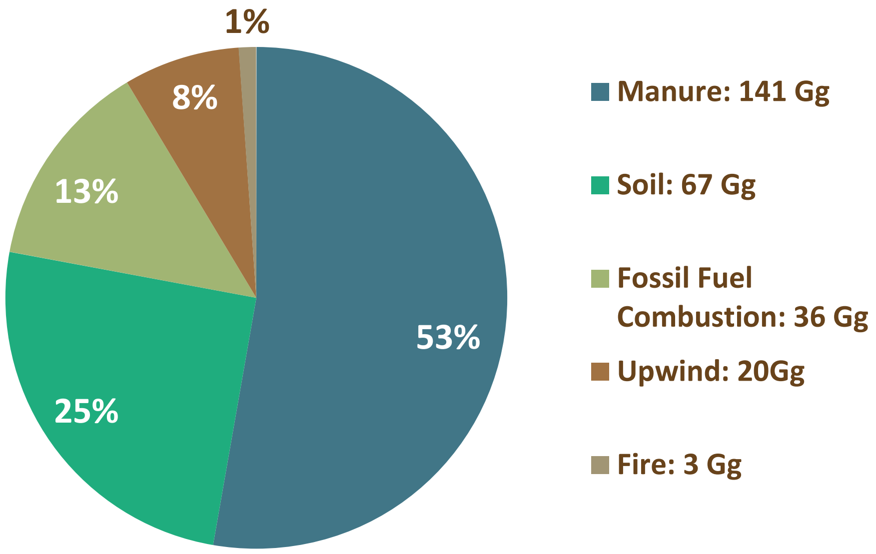
Statewide N Outputs and Storage: Net of Groundwater Denitrification

≈1.8 million tons (1628 Gg N yr^{-1})

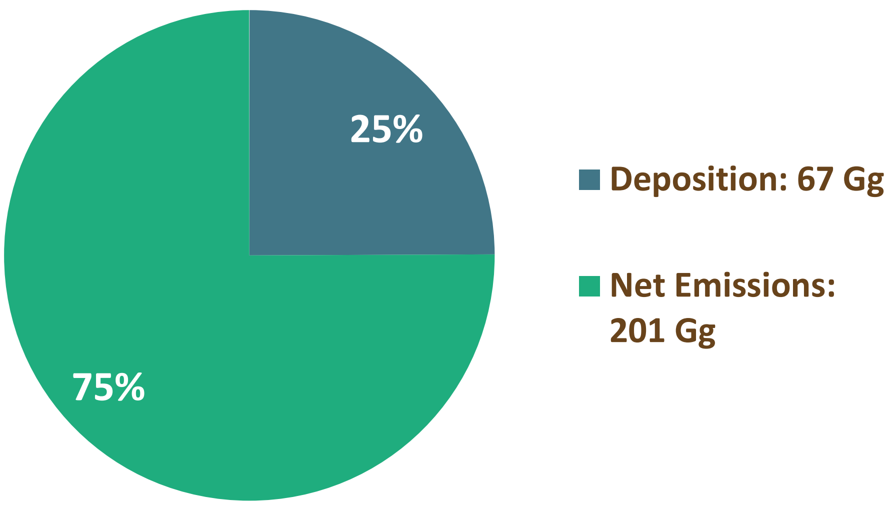


NH_3 Emissions:
221 thousand tons (201 Gg) N per year
(Ammonia emissions = 12% of total statewide N inputs)

NH_3 emissions by source
Total: 267 Gg N (294 thousand tons)



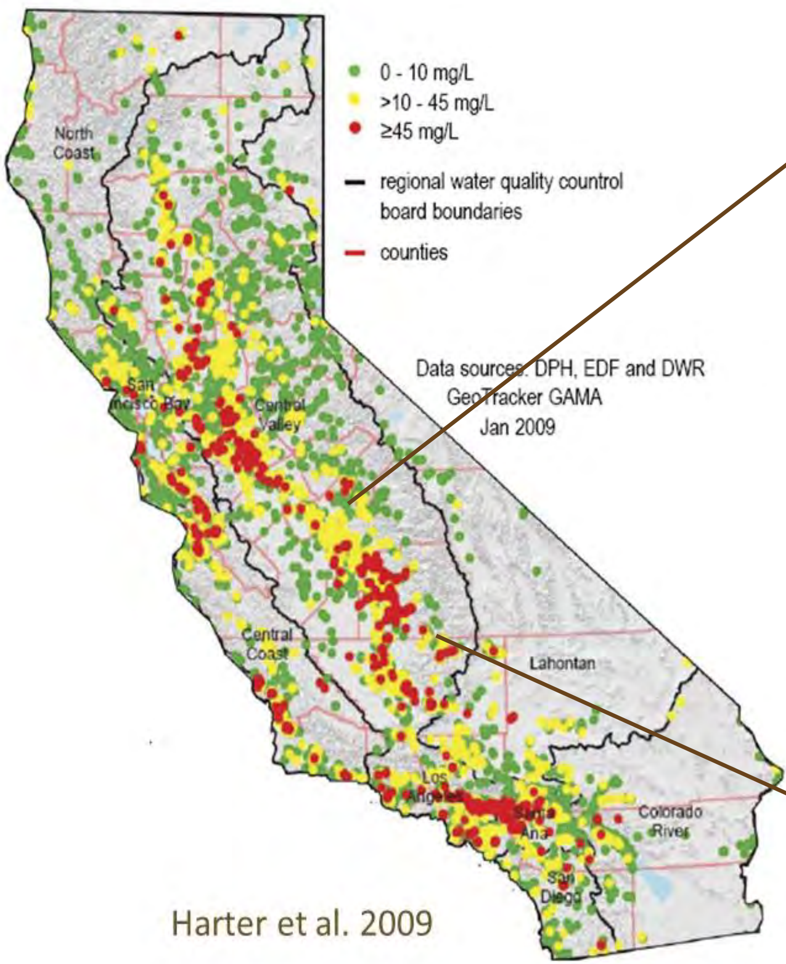
NH_3 deposition and net emissions
Total: 268 Gg N (295 thousand tons)



NH_4 emissions from livestock manure are based on CA-specific excretion estimate and EPA NH_4 emissions factor (high level of uncertainty due to limited field data)

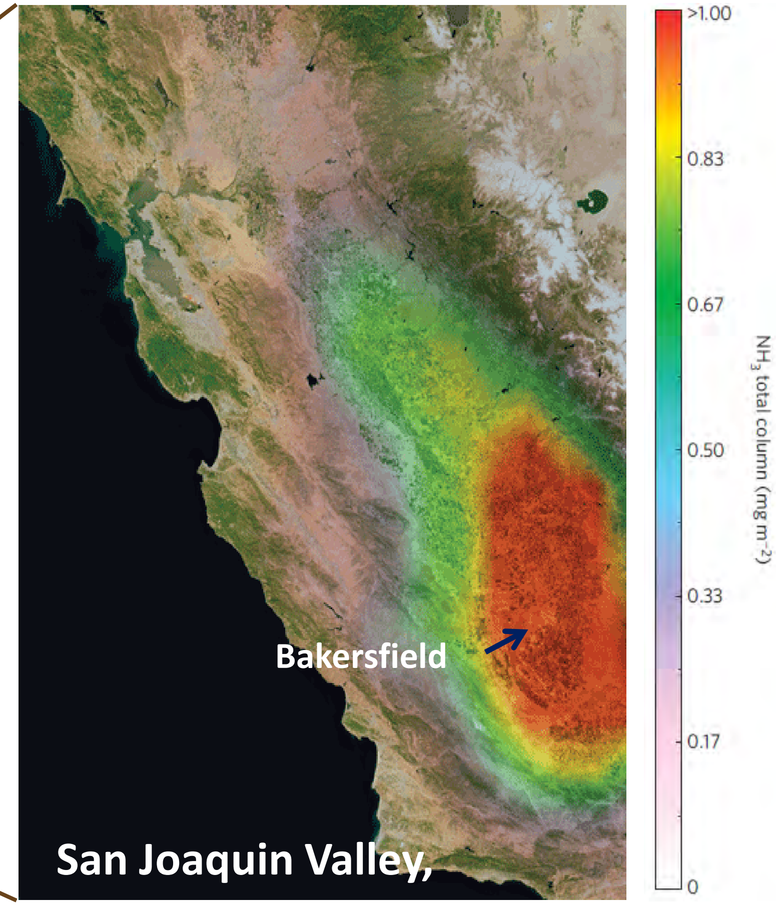
Co-location of Air and Groundwater Pollution: Environmental Justice Concerns

NO_3 in groundwater



Harter et al. 2009

NH_3 volatilization

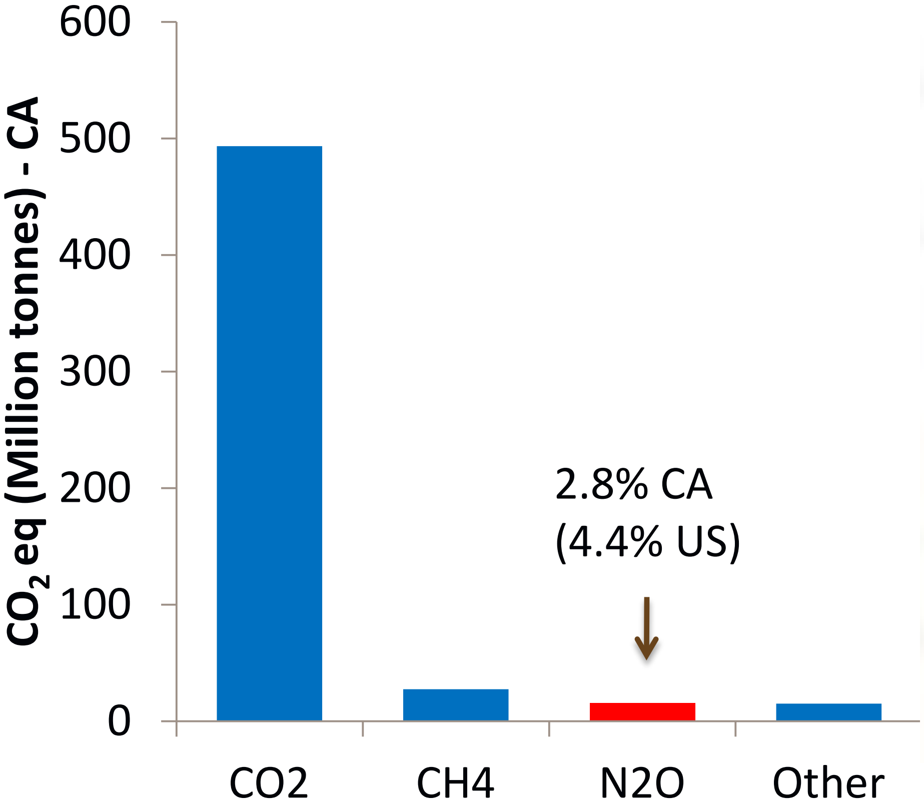


Infrared satellite data; Clarisse et al. 2009

N_2O: A Greenhouse Gas & Ozone Depleting Substance
(38 Gg N yr^{-1}) < 2% of statewide N output

Global Warming Potential

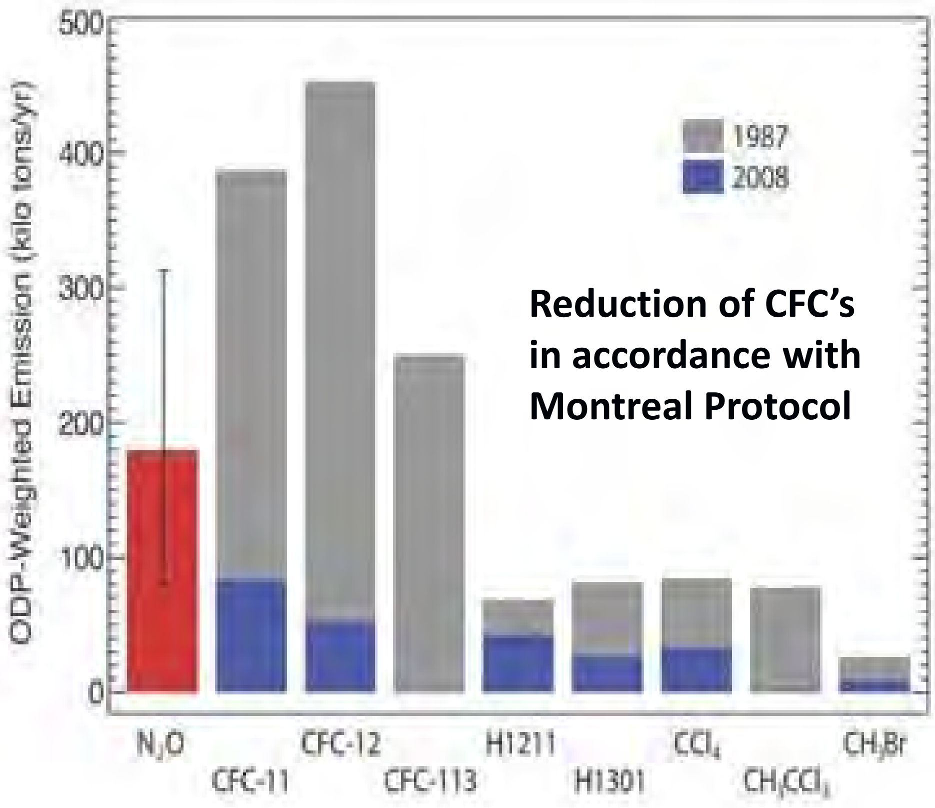
CA Greenhouse Gas Emissions (2009)



Source: California Air Resources Board

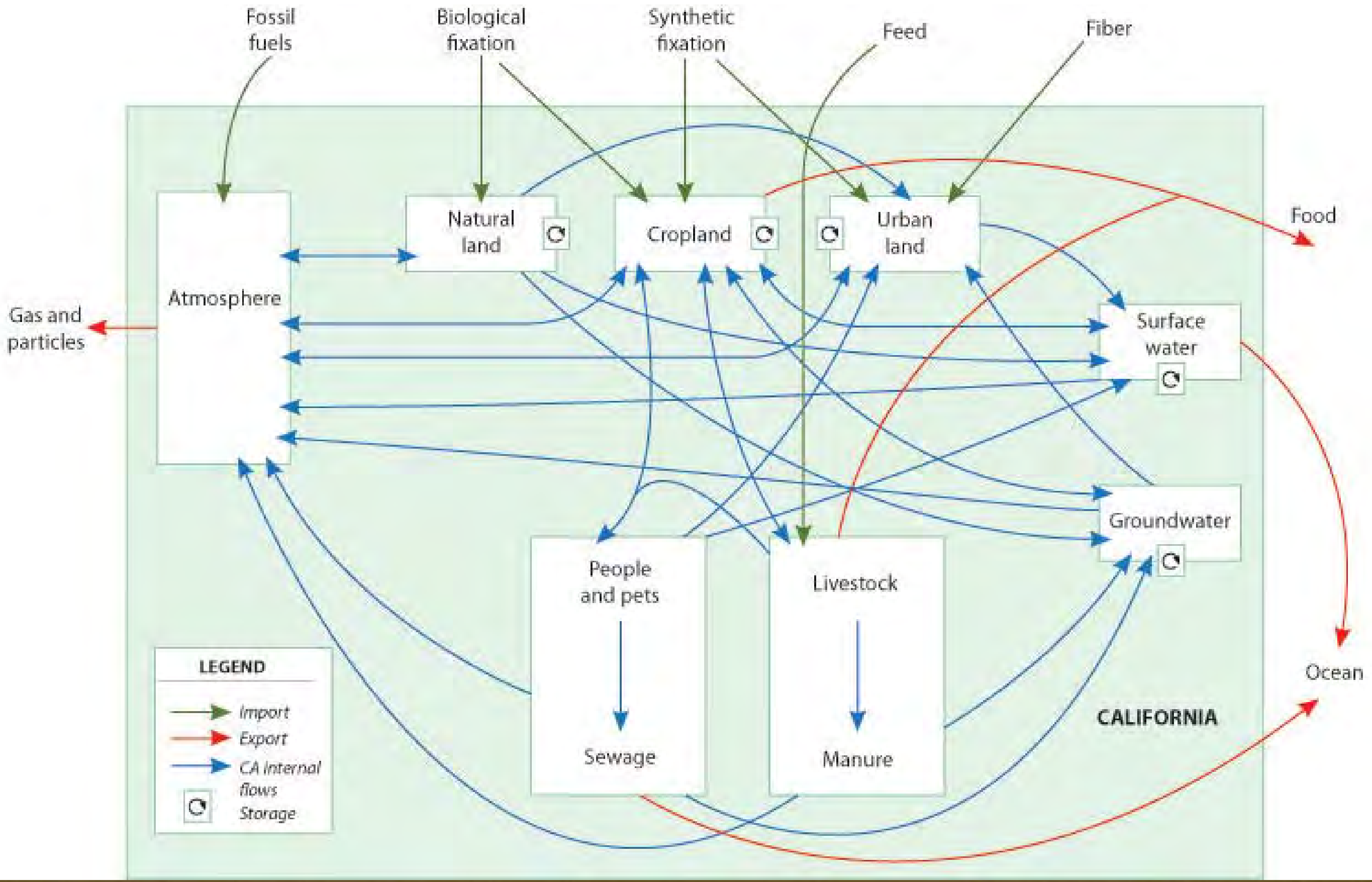
Ozone Depleting Potential

Global Emissions of Ozone Depleting Substances



Source: Ravishankara et al. 2009

Using N Flows to Prioritize Our Response



Key Strategies for Addressing N-Related Problems

1. Reduce inputs of new N into the state - Cascading Benefits

- Efficiency of energy and transport sectors
- N use efficiency in cropping systems (fertilizer, manure, water management, N budgeting)
- N efficiency of livestock systems (feeding strategies)
- Food waste & human dietary preferences

2. Target transfers of N between environmental pools

- NO_x and PM emissions from stationary and mobile sources
- NO_3 leaching and runoff from croplands and urban lands
- Leaching and discharge from point sources (e.g. wastewater)
- NH_4 volatilization & N_2O emissions from soil

3. Adapt to an N-rich environment

- Drinking water treatment
- Alternative drinking water sources
- Crop N budgets that account for N in irrigation water

Concluding Thoughts

- Trade-offs are inevitable with many N management strategies
  - The problem of secondary “cross-media” transfers

  Example: Incorporating manure into soil can reduce NH_3 volatilization, increase plant N uptake, but may also increase NO_3 leaching.

- Appropriate strategies will require an <u>integrated approach</u> that considers local economic and environmental conditions
- Solutions will require integrated monitoring and management across media (water, air, climate) at multiple geographic scales (field, farm, watershed, air basin).

Complexity + spatial dispersion → high transaction costs

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Stakeholder Advisory Committee

- California Rangeland Conservation Coalition
- Defenders of Wildlife
- Citrus Research Board
- Organic Fertilizer Association of California (OFAC)
- CA Rice Producer's Group
- California Rice Commission
- California Farm Bureau Federation (CFBF)
- Almond Board of California
- Roots of Change
- Sustainable Conservation
- Community Water Center (CWC)
- Western Growers Association
- Hines Nurseries
- University of California Cooperative Extension (UCCE)
- California Strawberry Commission
- CDFA Fertilizer Research and Education Program (FREP)
- US Environmental Protection Agency (US EPA)
- San Joaquin Valley Air Pollution Control District
- California Water Institute
- Fresh Express/Chiquita
- Western United Dairymen
- McCormack Sheep and Grain
- International Plant Nutrition Institute (IPNI)
- Environmental Defense Fund (EDF)
- Ag Services (Salinas)
- Western Plant Health Association
- California Certified Organic Farmers (CCOF)
- Rominger Brothers Farms
- Community Alliance with Family Farmers (CAFF)
- Fetzer/Bonterra Vineyards
- California Regional Water Quality Control Board, Central Coast Region
- California Climate and Agriculture Network

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